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ELECTRIC AND MAGNETIC FIELD CALCULATIONS IN SUPPORT OF BIRD MIG--ETC(U)
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ELECTRIC AND MAGNETIC FIELD CALCULATIONS IN SUPPORT OF BIRD MIGRATION STUDIES AT THE WISCONSIN TEST FACILITY.

(9) Technical rept.,

U. S. Naval Electronic Systems Command
Washington, D. C.

Prepared by

(10) D. Lanera
IIT Research Institute
10 West 35th Street
Chicago, Illinois 60616

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FOREWORD

This document reports IITRI's work activities in support of bird migration studies at the Wisconsin Test Facility in 1977. A large part of this effort was expended in the development of a computer program which can calculate electric and magnetic fields in the three-dimensional space above ELF antenna, taking into account its actual routing. The work was performed as part of Naval Electronic Systems Command Contract N00039-76-C-0141, and was under the direction of LCdr. W. S. Phillips, PME 117-214.

Respectfully submitted,

IIT RESEARCH INSTITUTE

D. Lanera
Associate Engineer

APPROVED

R. D. Carlson
Program Manager

A. R. Valentino
Manager, EM Effects

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1. INTRODUCTION

The possible effect of extremely low frequency (ELF) electric and magnetic fields on bird migration has been a subject of concern for some time. Consequently, the Navy funded a research project to study the question, using the Wisconsin Test Facility (WTF) as the ELF source. This project, led by Dr. T. C. Williams of Swarthmore College, uses radar tracking techniques to record the path of migrating birds as they fly over the WTF.[1]

An important element in Dr. Williams' work is the knowledge of electric and magnetic fields in the space just above the WTF antenna where the free flying birds are observed during migration. It has been the task of IIT Research Institute to estimate these field values using analytical techniques. Accordingly, a computer program has been developed to implement the analysis and permit rapid computation of the requisite field levels along any selected path. This report describes IITRI's analytical effort and presents the electric and magnetic field profiles calculated to support Dr. Williams.

2. ANALYSIS REQUIREMENTS

The Wisconsin Test Facility consists of two antenna elements installed in a cross-shaped pattern, as shown in Figure 1. Each antenna element is approximately fourteen miles long and is composed of a cable suspended from poles at an average height of thirty feet above the ground. The antenna elements terminate in grounding electrodes which consist of bare, horizontal, buried wires. The antenna current may be as high as 300 A and is modulated in the frequency band 72-80 Hz. The two antenna elements can be operated independently or together in any phase relationship.

The flight paths along which profiles of the electric and magnetic fields were requested are shown in Figure 2, and designated as A, B, C, D, and E. Profiles were requested at altitudes of 50, 100, 200 and 500 meters for line A and at 150 meters for lines B, C, D, and E. Since only the N-S antenna was used during the bird migration observations, it was requested that the calculations be made for the case of the N-S antenna element operating alone.

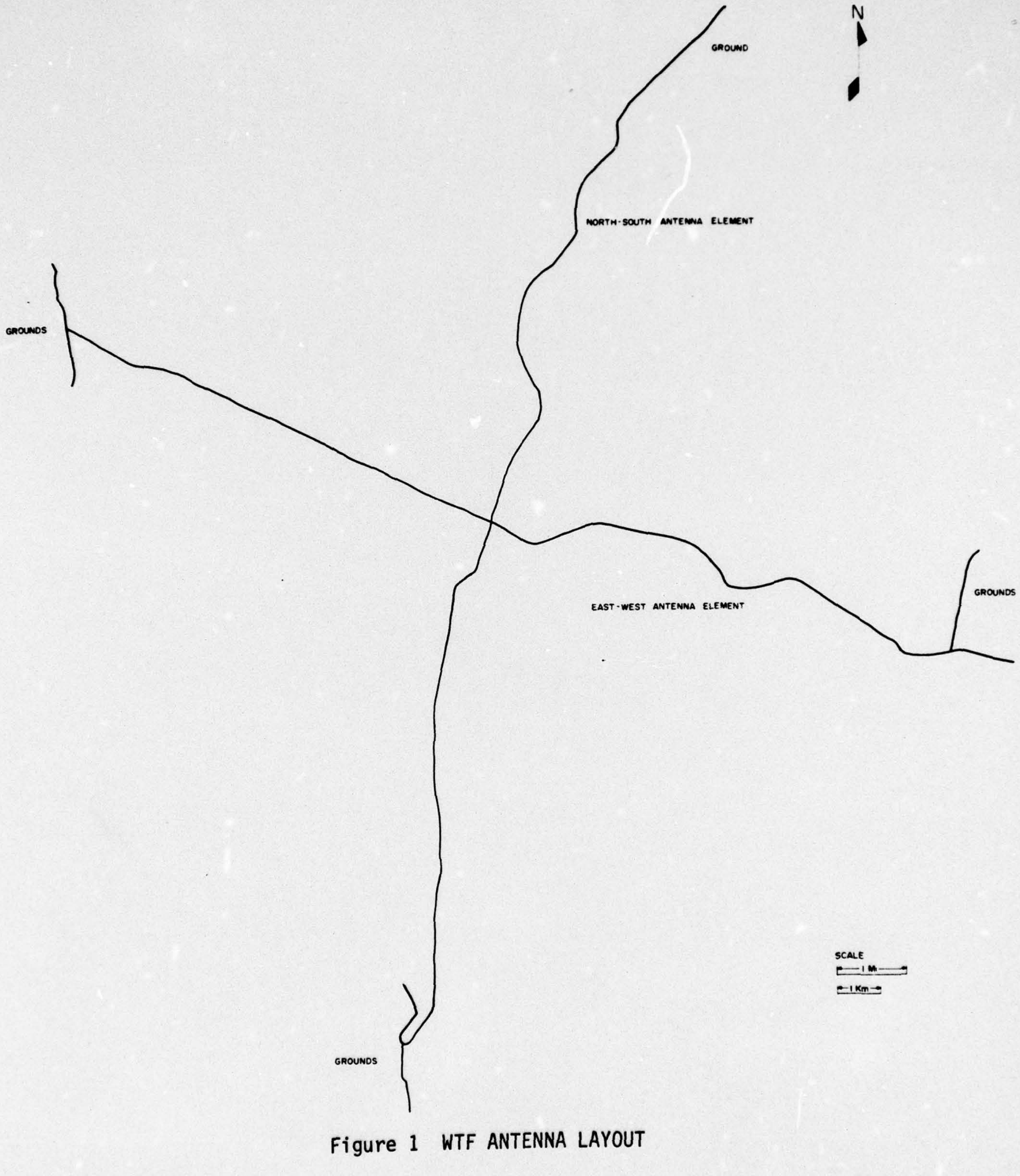


Figure 1 WTF ANTENNA LAYOUT

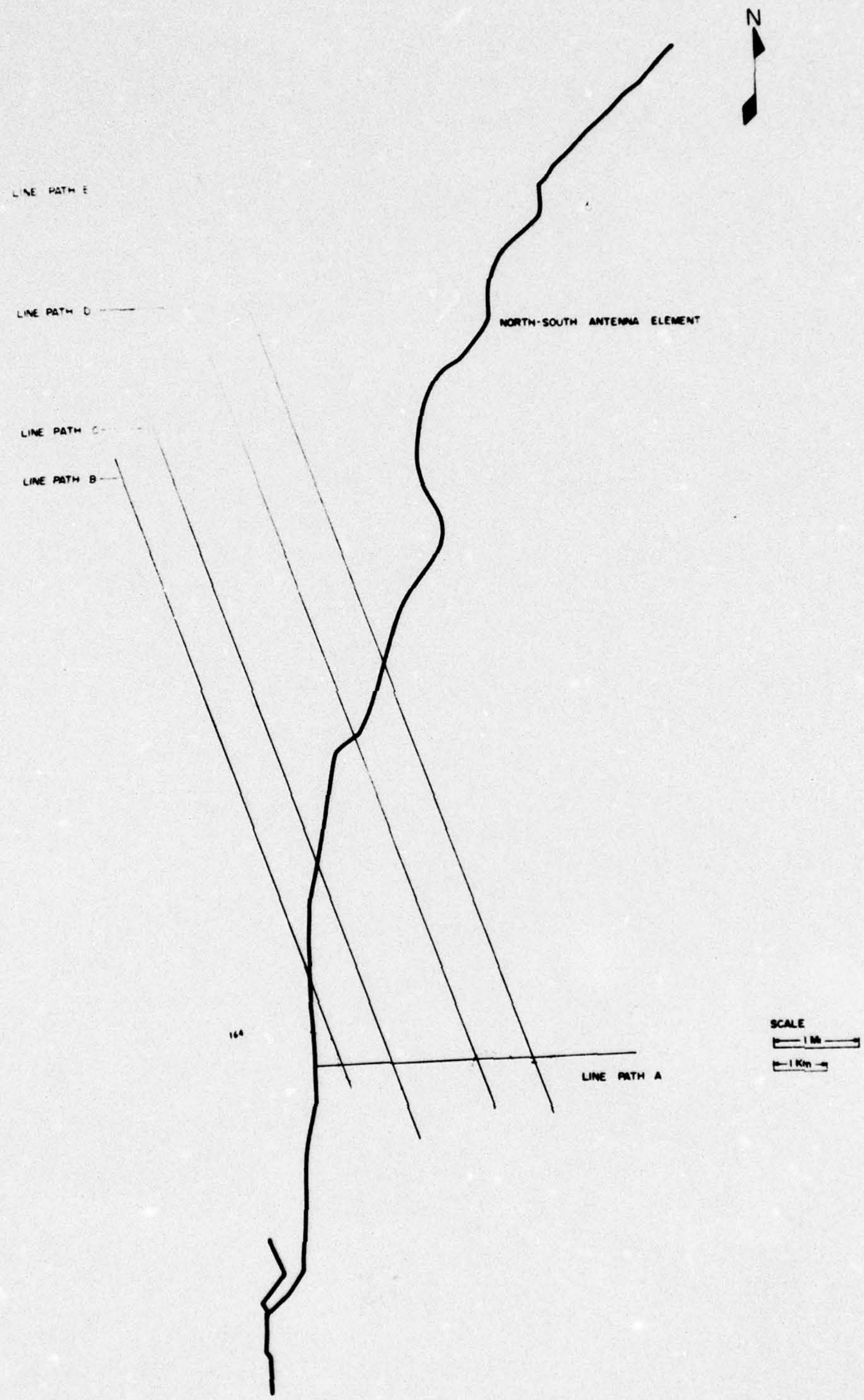


Figure 2 LINE PATHS A, B, C, D, E, AND THE N-S WTF ANTENNA

3. ANALYTICAL MODEL

To facilitate computer calculations, a piecewise linear approximation to the actual antenna route was used. This is shown in Figure 3. Each segment is defined by its two end points which are called nodes. Each node is geographically located in terms of an x, y component pair with respect to an arbitrary but consistent reference coordinate system.

The terminal grounding electrodes were modeled as point grounds located at the furthest extremities of the system. This simplification is adequate since the computer program is only valid for, and was only used for, field points remote from (by at least a skin depth) and between the antenna end points.

For this analysis it was assumed that the earth is isotropic and homogeneous. The conductivity selected for use in these calculations was 2.6×10^{-4} mhos/meter, as derived from measurements taken in Wisconsin by GTE Sylvania.[2]

Since the required field points are sufficiently close to the antenna and remote from its end points, we may assume that the field distorting effects of the antenna ends may be neglected. However, since the flight paths cross the antenna at altitudes as low as 50 meters, local variations in the antenna orientation are important to the field structure. It was decided, therefore, to refine and improve on the single straight line antenna model used in past calculations.[1] This was accomplished by recognizing that the local variations in antenna orientation are only important when the field point is close to the antenna. The implementation employed establishes a zone of influence around each field point which designates that portion of the antenna which dominates the field at that point. The portion of the antenna so designated is then replaced by a long line of the same average orientation. Equations derived from a long line model are then employed to calculate the fields. The necessary equations were obtained from available literature[3,4] and are described in Figure 4.

A computer program was set up to utilize the equations discussed above, combine them with the antenna model, and generate electromagnetic field value estimates. The program was written in FORTRAN V language and implemented on a UNIVAC 1108. Basically, the algorithm takes a line path of the type shown in Figure 2 and samples it at regular intervals to define field points. The electric and magnetic fields of these points are then calculated.

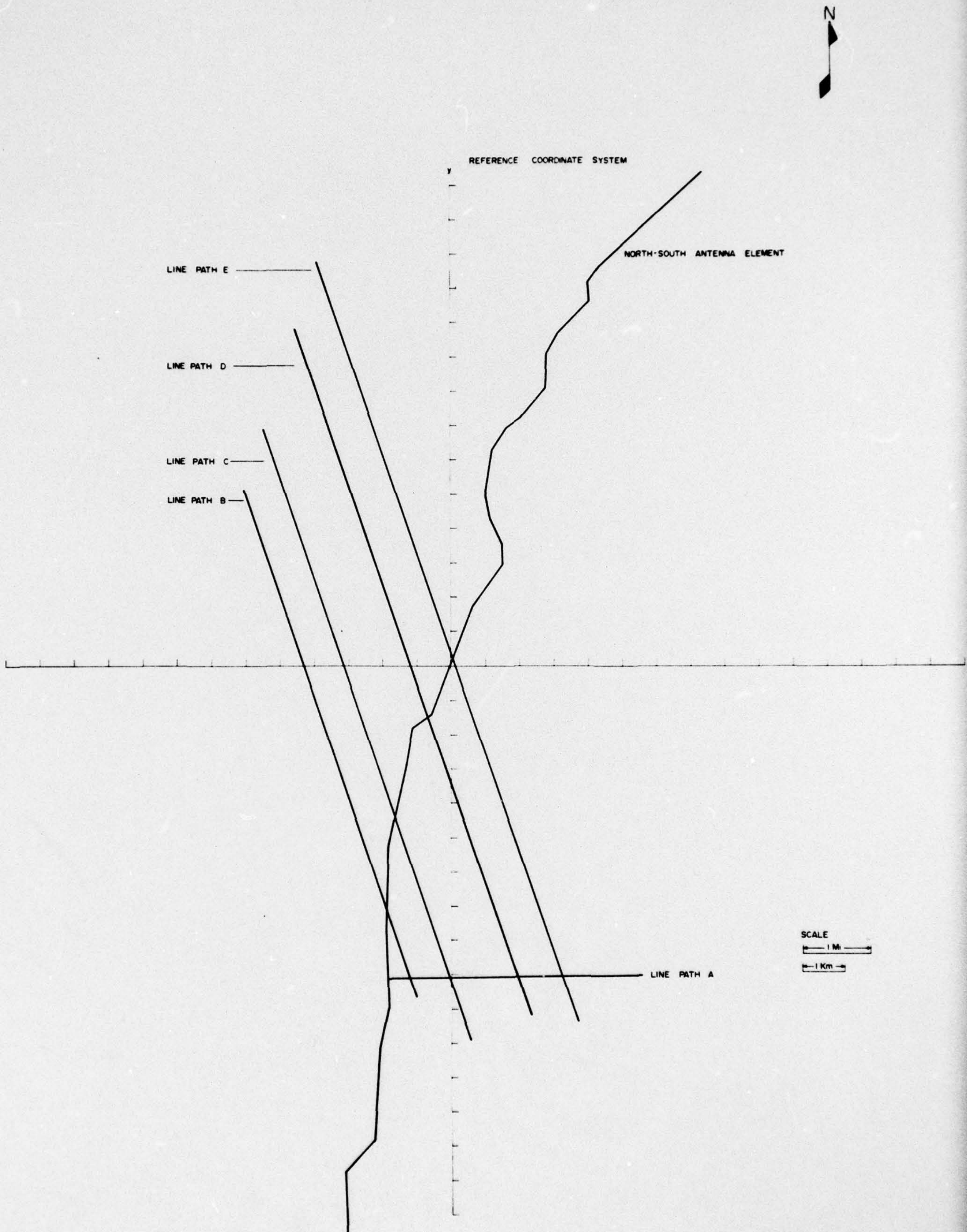
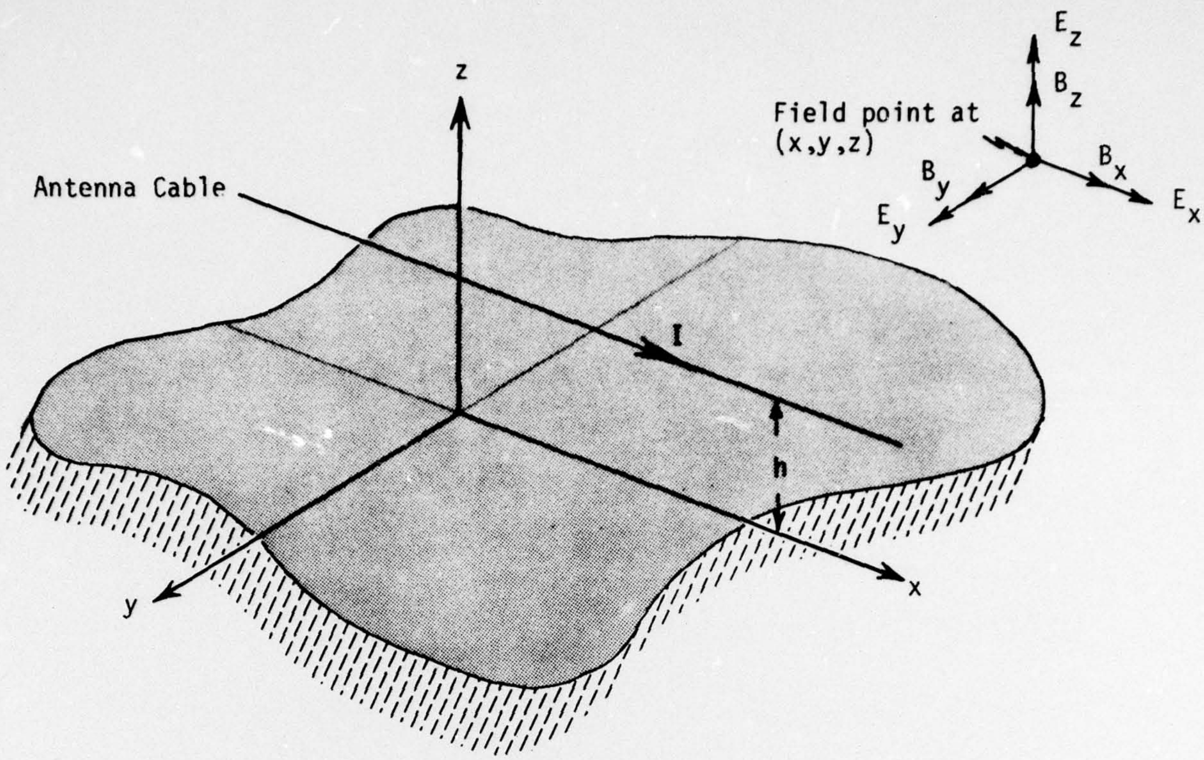


Figure 3 LINE PATHS A, B, C, D, E, AND THE NORTH-SOUTH DIGITIZED ANTENNA IN A COMMON REFERENCE COORDINATE SYSTEM



a) Coordinate System and Geometry for Field Calculations

$$E_y \simeq E_z \simeq B_x \simeq 0$$

$$E_x \simeq \frac{-j\omega\mu_o I}{2\pi} \, \ell n \sqrt{\frac{y^2 + (d+z+h)^2}{y^2+z^2}} \text{, volts/meter}$$

$$B_y \simeq \frac{10^4 \mu_o I}{2\pi} \left\{ \frac{(d+z+h)}{y^2 + (d+z+h)^2} - \frac{z-h}{y^2 + (z-h)^2} \right\} \text{, Gauss}$$

$$B_z \simeq \frac{-10^4 \mu_o I y}{2\pi} \left\{ \frac{1}{y^2 + (d+z+h)^2} - \frac{1}{y^2 + (z-h)^2} \right\} \text{, Gauss}$$

$$d = \delta(1-j), \quad \delta = (2/\omega\mu_o\sigma)^{1/2}$$

where: I = antenna current, amperes
$\omega = 2\pi f$, ELF angular frequency, radians/second
μ_o = permeability of free space ($4\pi \times 10^{-7}$), Henrys/meter
σ = earth conductivity, Siemens/meter

b) Defining Equations[3,4]

Figure 4 CALCULATION OF ELECTRIC AND MAGNETIC FIELD LEVELS ABOVE AN ELF ANTENNA

4. CALCULATIONS AND RESULTS

The computer program was run to calculate the electric and magnetic field magnitudes along the bird flight lines designated as A, B, C, D and E in Figure 3. The altitudes were 150 meters for line paths B, C, D and E; and 50, 100, 200 and 500 meters for line path A. The calculations were made for the case of the N-S antenna operating alone at 300 A and 76 Hz.

The field magnitudes calculated in these runs have been plotted on semi-log graphs and are shown in Figures 5-14. The electric and magnetic field magnitude profiles are shown on separate graphs for clarity. Figures 5 and 6 show the electric and magnetic field profiles for line path A at various altitudes. The results are as expected and show field magnitudes which are highest over the antenna and then decrease as the distance increases. A few kilometers away and beyond, no difference is observable among the fields at various altitudes. The remaining figures deal with the electric and magnetic field profiles of lines B, C, D and E. As expected, they too show a considerable peak when crossing over the antenna.

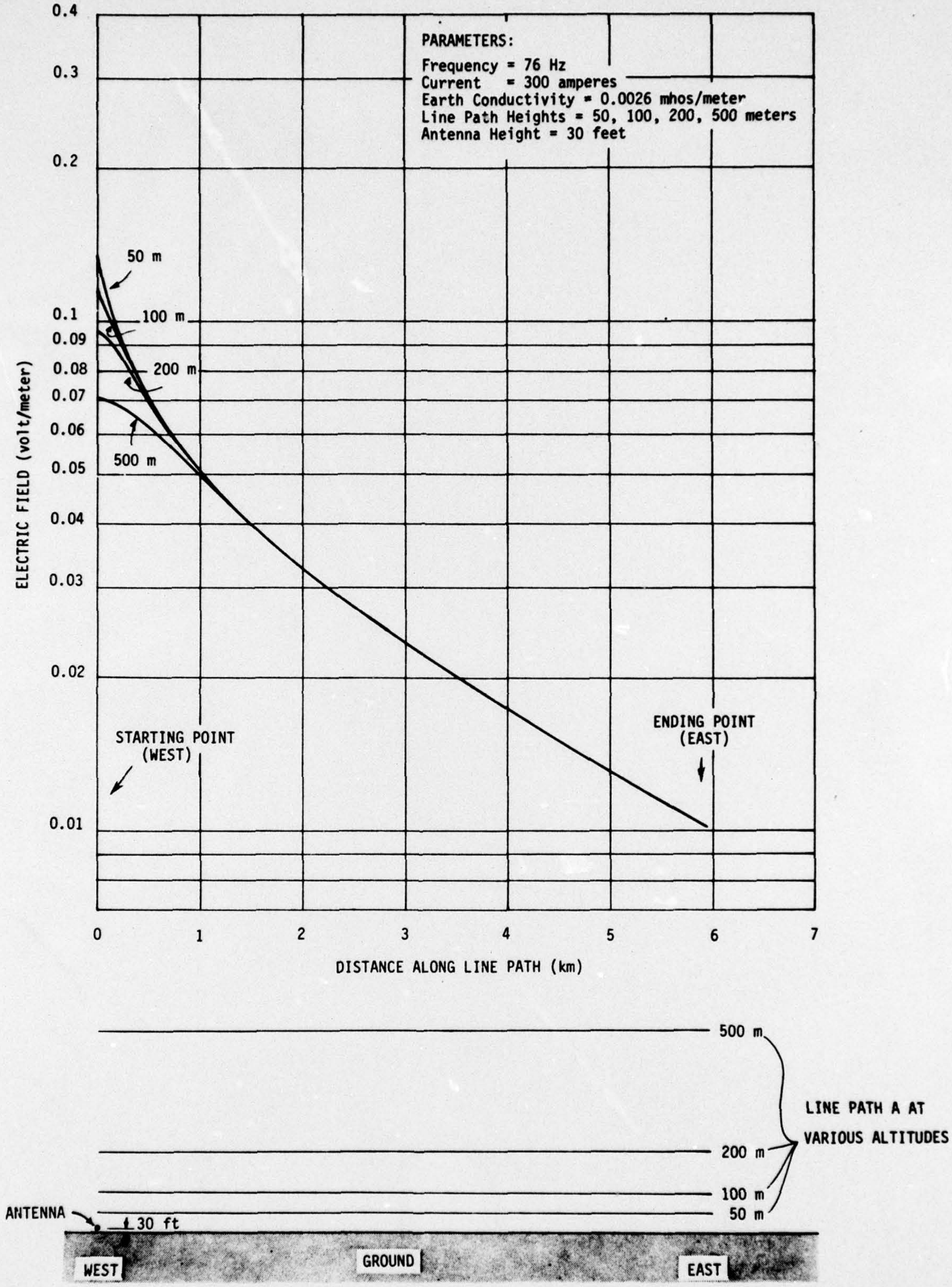


Figure 5 ELECTRIC FIELD ALONG LINE A DUE TO THE N-S WTF ANTENNA

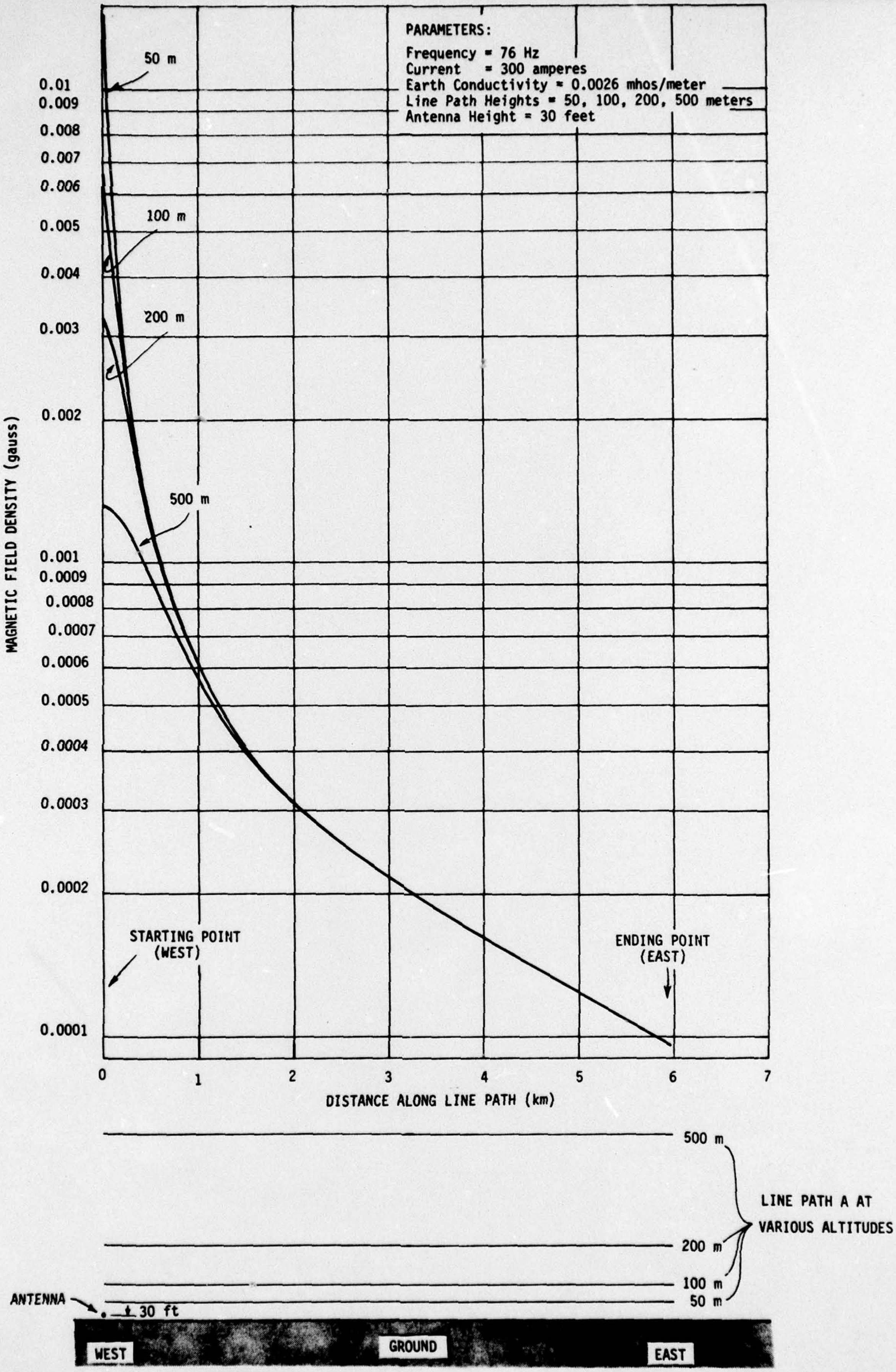


Figure 6 MAGNETIC FLUX DENSITY ALONG LINE A DUE TO THE N-S WTF ANTENNA

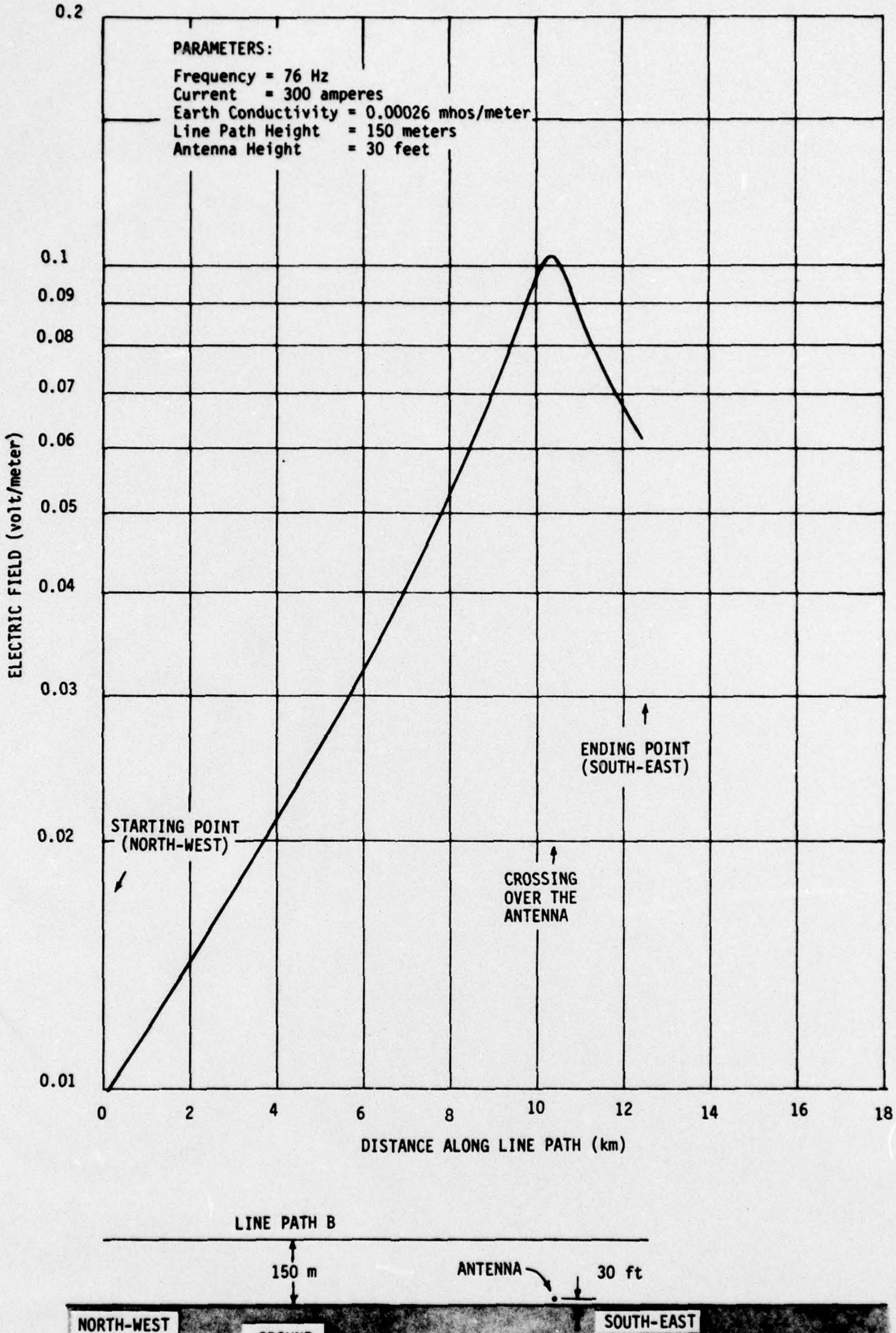


Figure 7 ELECTRIC FIELD ALONG LINE B DUE TO THE N-S WTF ANTENNA

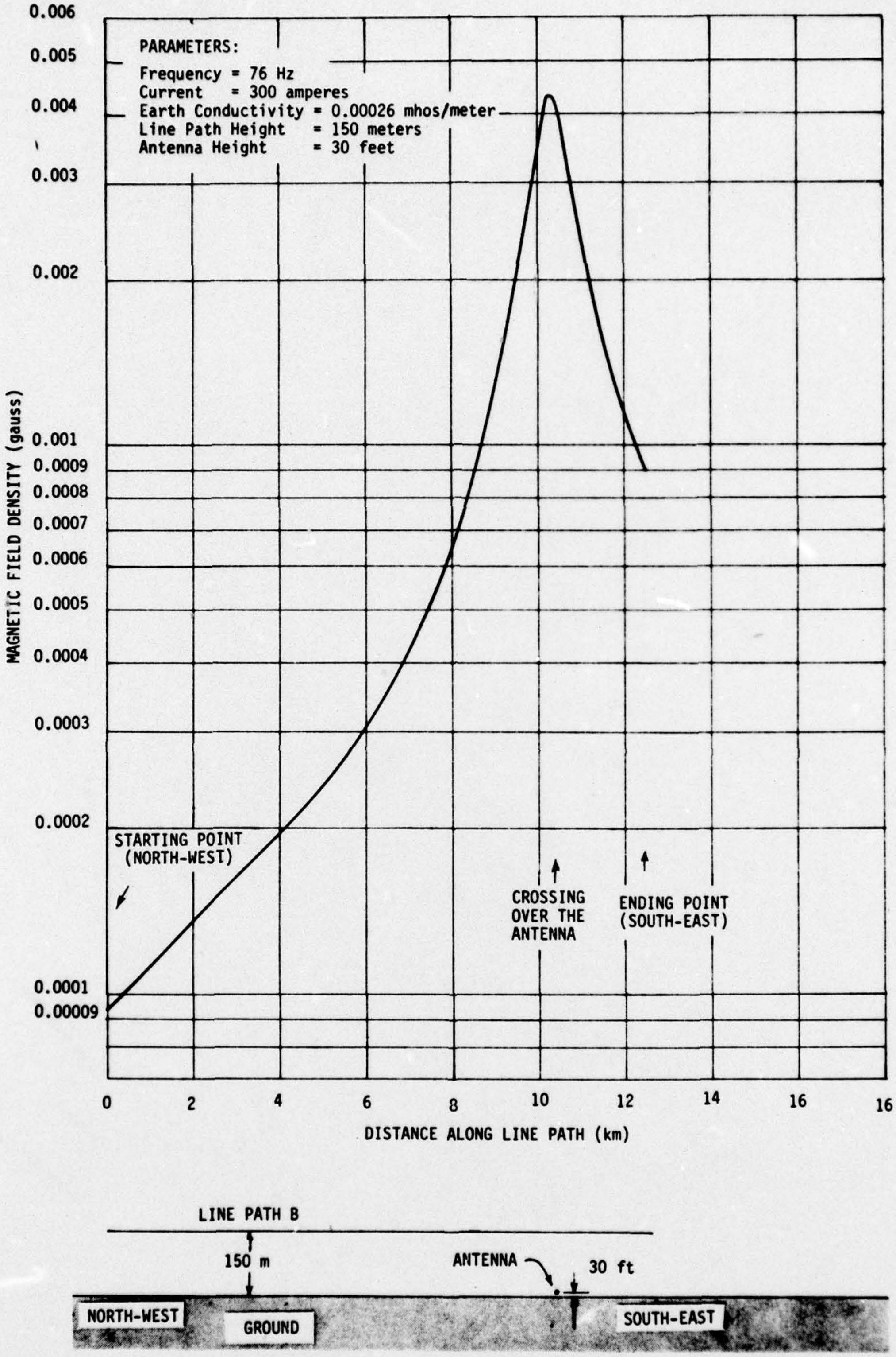
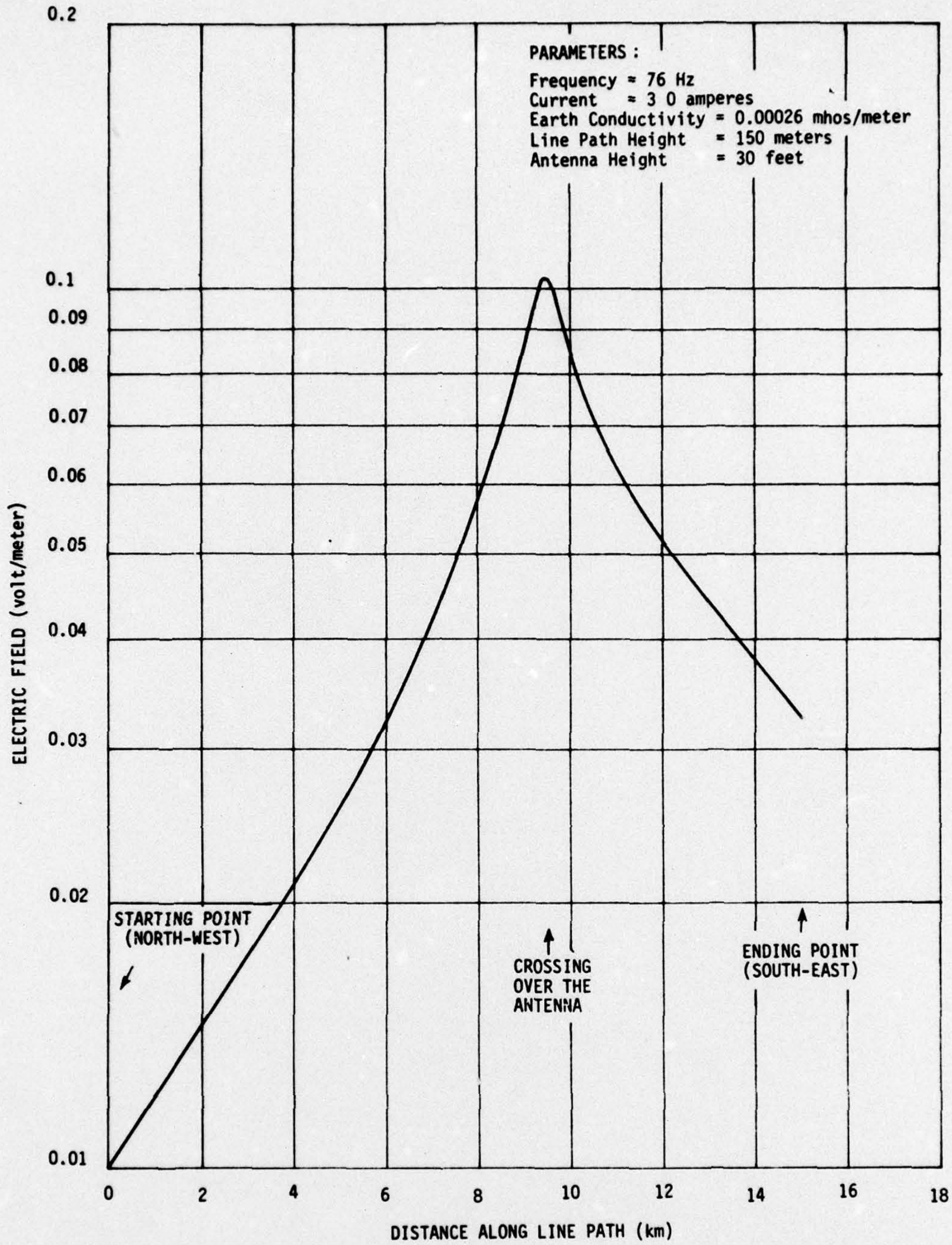


Figure 8 MAGNETIC FLUX DENSITY ALONG LINE B DUE TO THE N-S WTF ANTENNA



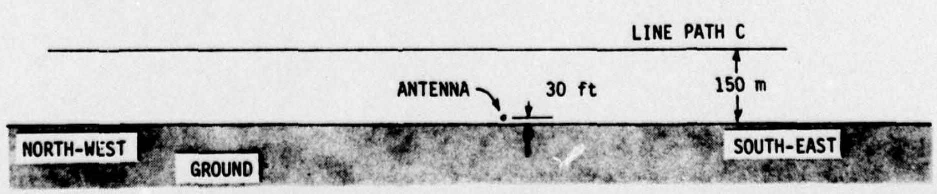


Figure 9 ELECTRIC FIELD ALONG LINE C DUE TO THE N-S WTF ANTENNA

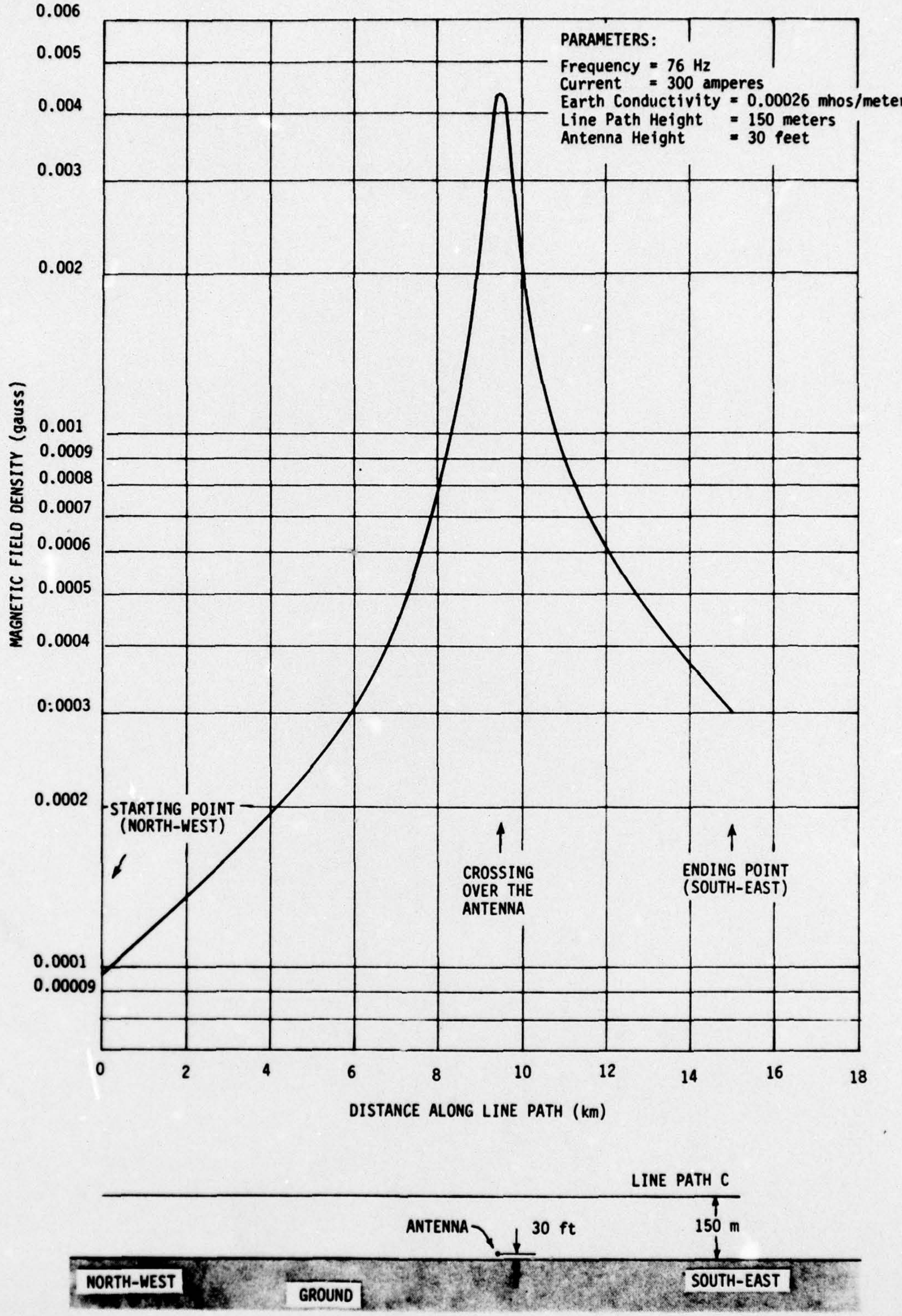


Figure 10 MAGNETIC FLUX DENSITY ALONG LINE C DUE TO THE N-S WTF ANTENNA

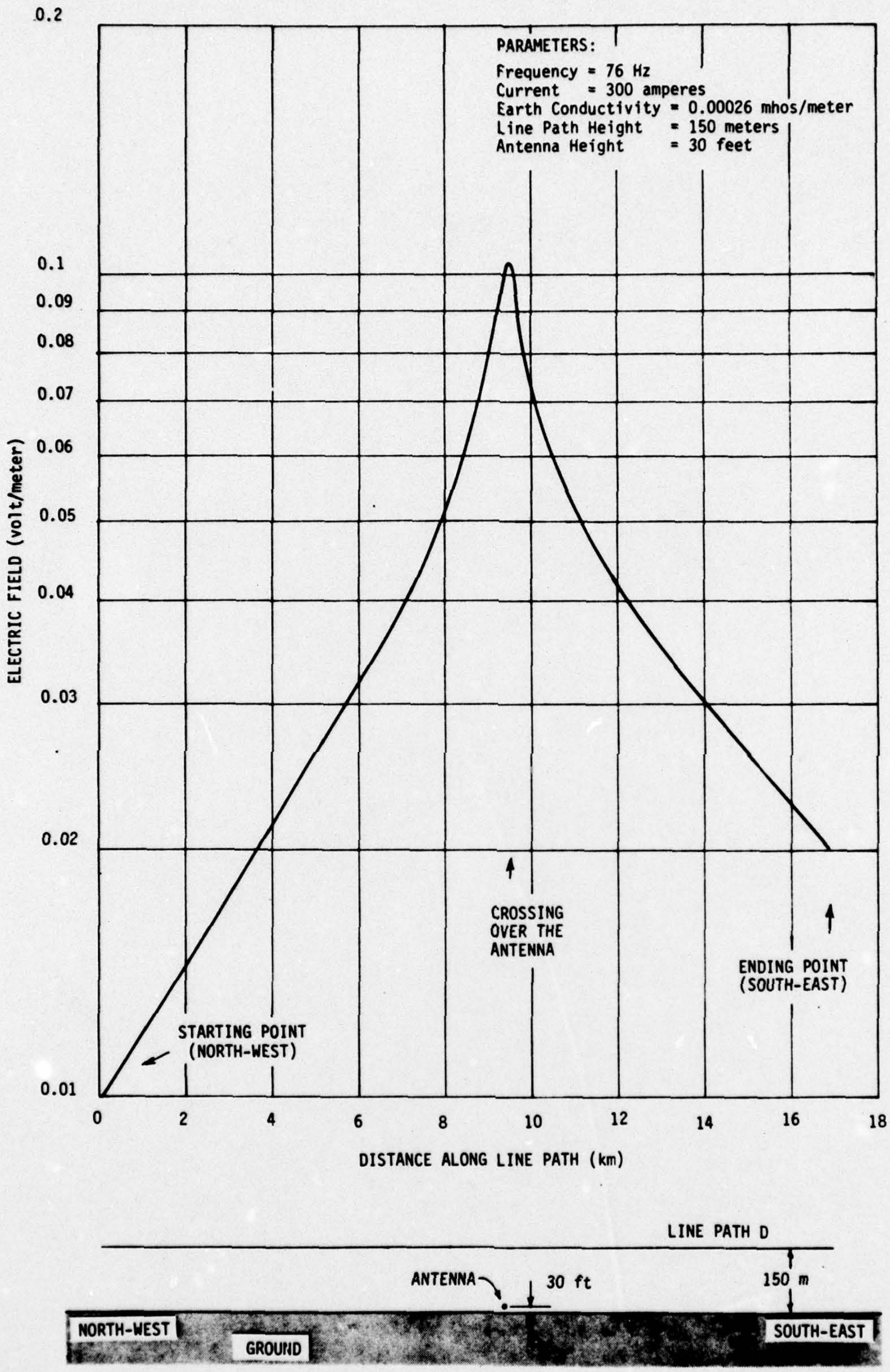


Figure 11 ELECTRIC FIELD ALONG LINE D DUE TO THE N-S WTF ANTENNA

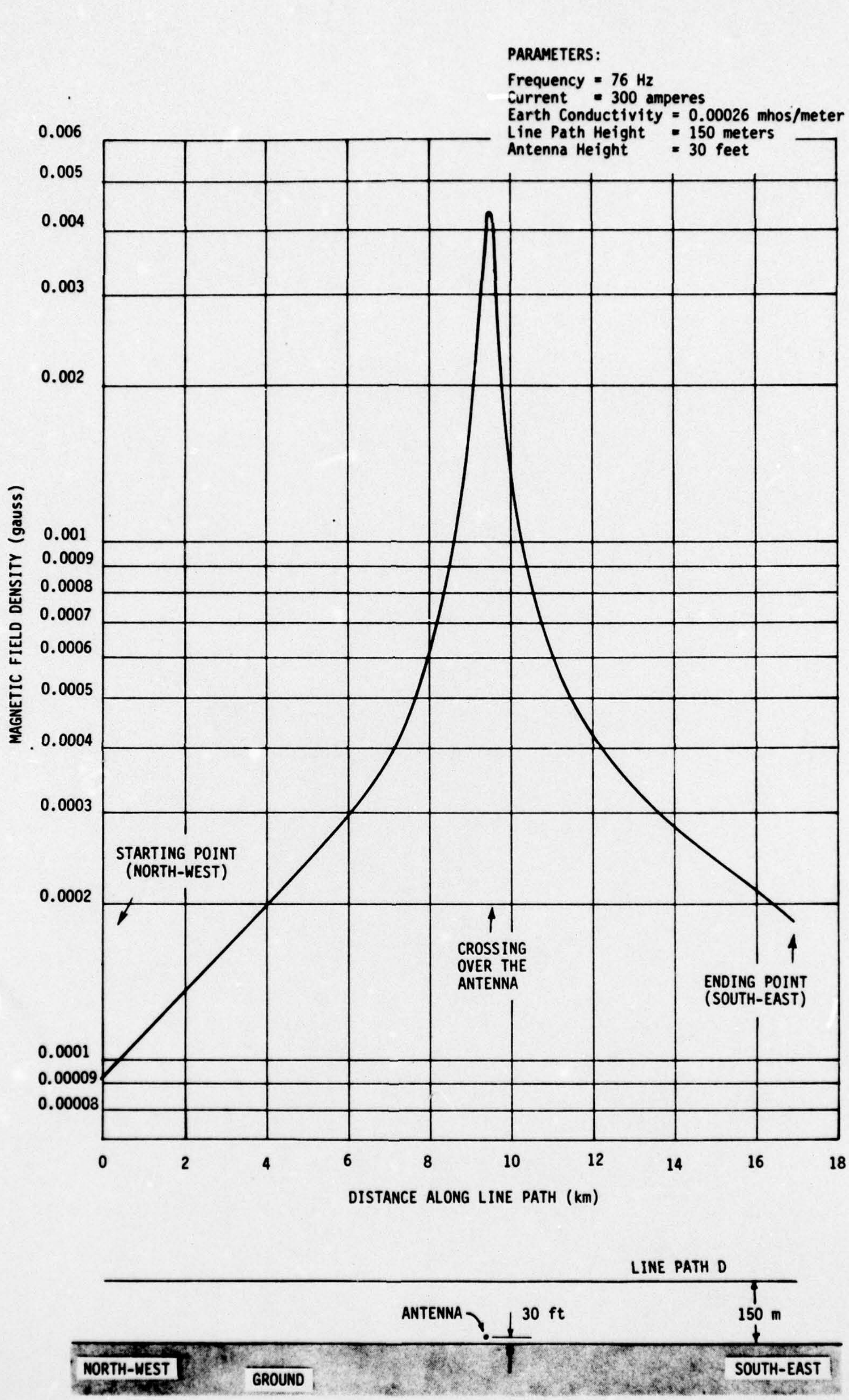


Figure 12 MAGNETIC FLUX DENSITY ALONG LINE D DUE TO THE N-S WTF ANTENNA

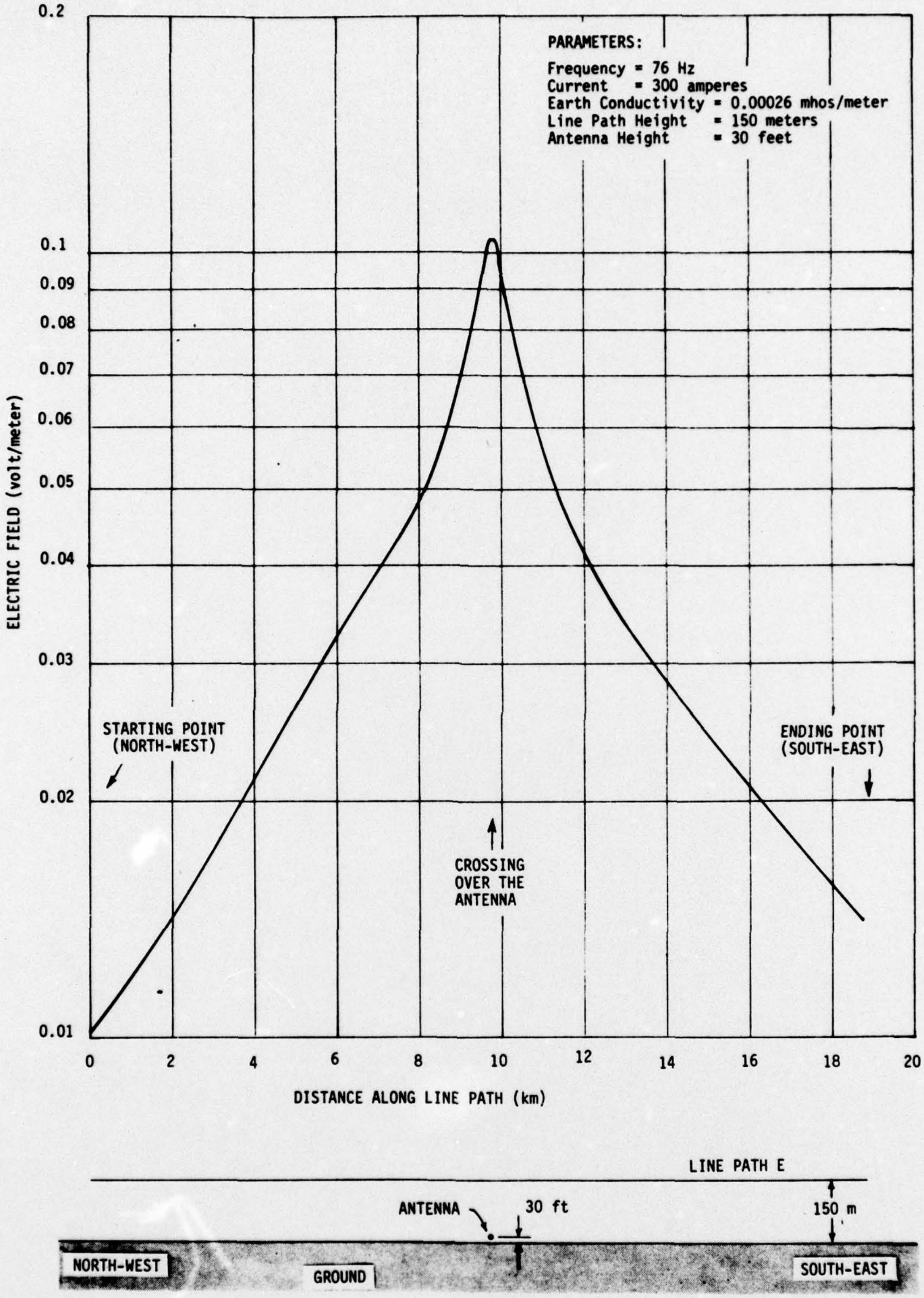


Figure 13 ELECTRIC FIELD ALONG LINE E DUE TO THE N-S WTF ANTENNA

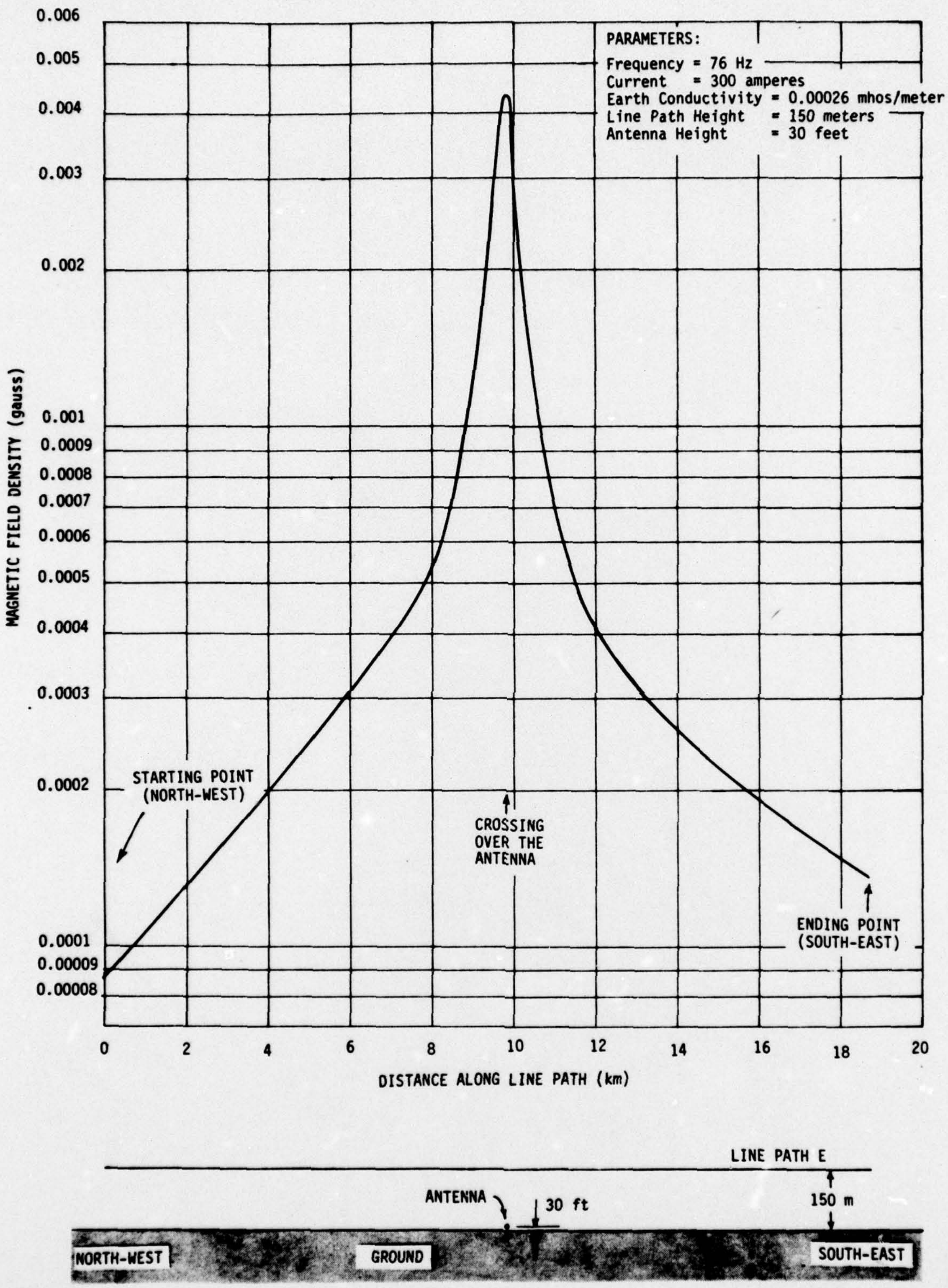


Figure 14 MAGNETIC FLUX DENSITY ALONG LINE E DUE TO THE N-S WTF ANTENNA

REFERENCES

1. Timothy C. Williams, A Radar Investigation of the Effects of Extremely Low Frequency Electromagnetic Fields on Free Flying Migrant Birds, Report, Contract No. N00014-75-00341.

2. GTE Sylvania, ELF Communications Seafarer Program, Site Survey Final Report, Michigan Region, Earth Conductivity Data, Report, Contract No. N00039-75-C-0309, April 1976.

3. Peter R. Bannister, The Image Theory Quasi-Static Fields of Antennas Above the Earth's Surface, NUSC Report No. 1061, 29 December 1969.

4. Martin B. Kraichman, Handbook of Electromagnetic Propagation in Conducting Media, NAVMAT P-2302, Library of Congress Catalog Card No. 77-609679, April 1976.

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The electric and magnetic fields at ELF, along specific line paths of birds at the Wisconsin Test Facility, are calculated in support of bird migration studies.

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